Adding Weather to Your Simulation

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Synopsis

Simulations and other computer intensive models frequently use limited weather scenarios – either rudimentary in capability or static and unvarying. The Battlefield Environment Division of ARL has been addressing this problem for many years. Capabilities exist in the Tri-Service Integrated Weather Effects Decision Aid (T-IWEDA) and the Target Acquisition Weapons Software (TAWS), in approximate radiative transfer models, such as the Sky-to-Ground Ratio (SGR) model, the illumination model LUME, and in the legacy models of the Electro-Optical Atmospheric Effects Library (EOSAEL). These models will be briefly reviewed and rapid-running methodologies for implementation will be presented. A complete set of references is also included.

1. Introduction

Applying weather to simulations is always problematic – detailed physics calculations are frequently required that involve significant amounts of computer time; even the simplest of atmospheric calculations frequently takes too long. Weather, however, is an important factor in determining the course and outcome of real battles. They affect virtually all battlespace functional areas from logistics and maneuver to C2 & ISR and combat engagements. Environmental data such as aerosol type, solar insolation, albedo, terrain elevations, soil moisture, accumulated snow cover, and other meteorological parameters are examples of the basic parameters that characterize the environment. However, to be useful in simulations, these data must be transformed into features, effects and impacts. Included in this area are weather features (clouds, fronts and thunderstorms, etc.), weather effects such as illumination, thermal emission, scattering and propagation losses that drive target contrast changes, and weather impacts that broadly describe the general environmental limitations on performance. Thus weather, atmospheric transport and diffusion processes, and the attenuating effects of the environment on the propagation of electromagnetic energy all impact target acquisition and high technology weapons performance. Converting these meteorological parameters and weather features into quantitative effects and impacts that are not computationally burdening for simulations is a difficult proposition. Not to be forgotten are high level simulations that deal

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with aggregated units. These simulations simply can not afford the computational burden that calculations for atmospheric effects on individual platforms and systems frequently require.

It would be ideal to field test each new weapon system or sensor in all conceivable battlefield weather conditions. That, however, has been found both impractical and uneconomical; simulations and/or tactical decision aids (TDAs) provide a more cost-effective method. The operation of EO devices follows a set of very predictable patterns, for example Beers law of attenuation. By using computer simulation programs (models), the systems developer can predict the operational behavior of each of the sensing devices or weapon systems under varying weather conditions. Such a set of models formed the framework for the Electro-Optical Systems Atmospheric Effects Library[1] (EOSAEL). Since the development of EOSAEL in the 80's, and the increase in computer speed since then, numerous other atmospheric models have been developed for use, not only in weapons testing, but also for representing physically correct weather effects in simulations. Table 1 presents a summation of some of these models, how they can be used and the size of the executable, which provides some degree of the level of implementation difficulty.

Table 1. Summation of available Atmospheric Effects Models

Model Name	Purpose	Usage	Size (kb)
BITS[2]	Provides rigorous transmittance calculations for broadband systems, replacing the Beer-Lambert law used in most obscuration models	Stand alone or Algorithm transfer	128
CLIMAT[3]	Provides averages and standard deviations or % occurrence of 11 meteorological surface parameters in each of 22 weather classes defined by obscuration type, visibility, absolute humidity, and cloud ceiling for various global geographical regions	Stand alone	100
CLTRAN[4]	Slant path transmission through six different clouds types	Stand alone or Algorithm transfer	116
COMBIC[5]	Calculates size, path length, concentration, and transmission for obscurant clouds of white phosphorus, plasticized white phosphorus, hexachloroethane, fog oil, infrared screeners, and artillery or vehicular-generated dust clouds	Stand alone or Tabular lookup	417
COPTER[6]	EO and MMW sensor obscuration resulting from helicopter downwash when operating over loose snow or dust	Stand alone or Algorithm transfer	120
GRNADE[7]	Obscuration produced by tube-launched L8A1 smoke grenades used for self-screening applications	Stand alone	124
IWEDA[8]	Provides impacts for systems, sub-systems and components	Stand alone	85,000

Model Name	Purpose	Usage	Size (kb)
IWEDA rules[9,10,11]	Unfavorable/marginal/favorable impacts for C2 & ISR systems	Thresholds and/or wargaming	Data Base
KWIK[12]	Calculates the number of smoke munitions required to reduce the probability of target detection to a specified level	Stand alone	200
LASS[13]	Effectiveness of smoke screens deployed at large fixed and semi-fixed military installations.	Stand alone	236
LUME[14]	Determines urban illumination levels at a distance from cities under clear or overcast conditions	Stand alone or Algorithm transfer	80
LZTRAN[15]	Determines gaseous absorption coefficients at 97 laser wavelengths due to water vapor and 6 dominant molecule types	Stand alone or Algorithm transfer	120
MPLUME[16]	Determines the degradation of imaging systems due to missile smoke plumes.	Stand alone	150
NMMW[17]	Provides refractivity for water vapor and oxygen and extinction and backscatter cross sections for fog, rain, and snow	Stand alone or Algorithm transfer	112
REFRAC[18]	Calculates the amount of curvature a ray of light experiences as it passes over a complex terrain surface	Stand alone or Algorithm transfer	120
SGR[19]	Approximate method for quantifying the amount of diffuse radiation that enters a sensor's field of view	Stand alone or Table construction	1006
SPEBE[20]	Determines the effects of the atmosphere and terrain on the performance of battlefield acoustic and/or seismic sensor arrays	Stand alone	125,000
STATBIC[21]	Textures mean cloud concentrations to simulate the effects of homogeneous atmospheric turbulence that produce the "random" eddy structures in obscurant plumes	Algorithm transfer	519
TAWS[8]	Target acquisition ranges for various weather conditions, targets and sensors	Stand alone	4290
WX4CM[22]	Rapid parametric curves for target detection under degraded atmospheric conditions	Equation implementation	N/A
XSCALE[23]	Horizontal or slant path transmission through haze, fog, rain, and snow for monochromatic or broadband wavelengths	Stand alone or Algorithm transfer	150

2. Atmospheric Effects Models

All of the models presented in table 1 are available to Government and Government contractors at no charge. In almost all cases model documentation and source code are also available. Since the EOSAEL was constructed in the 80's much importance was attached to their ability to perform rapidly and take up a minimum of computer memory. Thus, they may be used either in a stand alone manner or have the algorithm extracted for insertion elsewhere. All codes in table 1 are internally documented and have been validated either with measurements or against research-grade codes. Provided below is a synopsis of each of the models in table 1.

a. BITS (Broadband Integrated Transmissions) provides exact transmittance calculations for broadband systems operating in the ultraviolet through the far-infrared spectral regions by accounting for spectral dependence of the Beer-Lambert law across system bands. The model computes broadband integrated relative transmittances, accounting for detector, filters, system, atmosphere, source (target), and smoke and obscurant spectral characteristics. The spectral characteristics of these items are specified by the BITS user, who may either input spectral data or select certain data sets maintained by the module. The spectral transmittances of the atmosphere and mass extinction coefficient spectral data for the obscurant (available via COMBIC) are also required.

b. CLIMAT provides typical meteorological data and frequency of occurrence of various weather conditions. The climatology data include averages and standard deviations or percentages of occurrence of 11 meteorological surface parameters in each of 22 weather classes defined by obscuration type, visibility, absolute humidity, and cloud ceiling. This climatological data is for different regions of Europe, the Mideast, Korea, Alaska, Scandinavia, Central America, India, Southeast Asia, South America, and Mexico.

c. CLTRAN (Cloud Transmission) models slant path transmission through six different types of clouds. The six cloud types have been divided into stratiform and cumuliform groups. This model evaluates the slant path transmission under the assumption of horizontal homogeneity and a vertical variability of the extinction coefficient.

d. COMBIC (Combined Obscuration Model for Battlefield Induced Contaminants) model calculates the size, path length, concentration, and transmission for various types of smoke clouds: white phosphorus, plasticized white phosphorus, hexachloroethane, fog oil, infrared screeners, and artillery or vehicular-generated dust clouds. The model is designed to aid in battlefield scenario studies where many obscurant sources and observer-target lines of sight must be treated simultaneously. (c.f. STATBIC)

e. COPTER is a model to accurately and realistically describe the atmospheric obscuration effects of EO and millimeter wave sensors resulting from helicopter downwash when a helicopter is operating near a surface covered with loose snow or dust. This model predicts the spatial and temporal variations in transmission through the snow cloud which are dependent on wavelength, helicopter altitude and airspeed, snow cover characteristics, and meteorological conditions.

f. The GRNADE model computes the obscuration produced by tube-launched L8A1 smoke grenades used for self-screening applications. This model specifically addresses only current inventory systems; however, various optional inputs allow the user to specify characteristics for other developmental, experimental, or hypothetical systems, including 24 tube launchers and XM 76 infrared screening grenades. The model will treat any number of grenades assumed to be simultaneously launched and dispersed evenly along an elevated horizontal line perpendicular to the launcher heading. Obscuration effects in the first few seconds following launch are also accounted for.

g. IWEDA (Tri-Service Integrated Weather Effects Decision Aid) is a rule-based tactical decision aid that provides tactical and graphical analyses of how weapons systems will perform under varying environmental conditions. It combines data from weather forecasts and a set of Tri-Service rules with associated critical values to evaluate the effectiveness of user-selected weapons systems and tactical operations for periods up to 48 hours over the forecast area. For user-defined missions, systems, subsystems, and components, the impacts (favorable, marginal, or unfavorable) and the time periods are shown on weather effects matrices and color-coded map overlays.

h. IWEDA rules provide a method for selecting an appropriate platform, system, or sensor under given or forecast weather conditions. They provide qualitative weather impacts for platforms, weapon systems, and operations, including soldier performance, i.e. critical value thresholds for one or a combination of the environmental parameters that affect the system. The rules can be used in combat models for go/no-go situations.

i. KWIK (Cross Wind Integrated Concentration) predicts the number of smoke munitions required to reduce the probability of target detection to a given level. It also provides, in tabular form, the number of initial and sustaining rounds, fire interval and shell separations to produce a screen of input length and duration for various smokes and eight inventory munitions.

j. LASS (Large Area Screening Systems) determines the effectiveness of smoke screens deployed at large fixed, and semi-fixed, military installations. The outputs are symbolic maps displaying the direct and diffuse components of scene transmission as affected by a large area smoke screen. The digital maps can be used with appropriately scaled maps of any given fixed installation to assess the effectiveness of a smoke screen under various ambient meteorological and illumination conditions and various attack scenarios.

k. LUME (Light Urban Model Effects) is a preliminary urban illumination model for use in tactical decision aids and wargames which allows for more accurate prediction of target acquisition ranges and increased realism in simulations at night. This initial model predicts broadband brightness as a function of population and distance (> 10 km) from the city center under clear and overcast conditions.

l. LZTRAN (Laser Transmission) provides simple yet accurate algorithms for computing the gaseous absorption coefficient at monochromatic wavelengths (primarily laser lines) for horizontal or slant paths. Ninety-seven lines are included between 0.53um and 10.6um. The algorithms are simple polynomials in terms of temperature, pressure, and water vapor and can be easily implemented. These polynomials were obtained by applying curve fitting procedures to the results of detailed line-by-line calculations. LZTRAN can perform calculations on a slant path with maximum height of five kilometers.

m. MPLUME (Missile Plume) predicts the location and spread of the plume from a Hellfire missile and the transmittance at visible, 1.06, 3-5, and 8-12 micrometers along any line of sight near the plume. Radiance at 8-12 micrometers is also calculated. The code is based on curve fits to the result from a detailed plume calculation code and on an adaptation of a Gaussian plume model.

n. NMMW (Near Millimeter Wave) is a line calculation code used for computation of gaseous absorption coefficients at millimeter wavelengths between 10 and 1000 GHz. In addition, NMMW calculates refractivity for water vapor and oxygen, and extinction and backscatter cross sections for fog, rain, and snow.

o. REFRAC computes the amount of curvature a ray of light experiences as it passes over a complex terrain surface. Various surface profiles can be modeled, with refractive index gradient varying as a function of height above the local surface. Options allow either a spread of rays to be plotted or an observation angle to be determined when given target-observer orientations and the atmospheric structure.

p. SGR (Sky-to-Ground Ratio) computes the sky-to-ground ratio, contrast transmission, transmission, path radiance, and zero-range-to-target background radiance for a user-specified observer (sensor) and target pair, situated on a slant path in the lower atmosphere for 19 different aerosols. The calculations are performed in one of three user-selectable bands: visible, mid-infrared, and far-infrared.

q. SPEBE (Sensor Performance Evaluator for Battlefield Environments) is a software package for predicting the performance of acoustic/seismic battlefield sensors and the acoustic/seismic detectability of military operations. SPEBE provides access to the best available models for calculating transmission of acoustic and seismic signals from the source to the sensor. Calculations that can be performed and displayed by SPEBE include probabilities of detection for many types of ground and air vehicles, accuracy of target bearings from a sensor array, and accuracy of target locations from a sensor network.

r. STATBIC generates a scaled concentration fluctuation field that can be multiplied times COMBIC's smooth, mean Gaussian cloud concentrations. This simulates the effects of cascading eddy energies in turbulence that give rise to a spatially correlated distribution of eddy sizes. STATBIC implements a modified fractal with a fractal dimension that changes with width of the smoke or dust plume. This distribution has been derived theoretically based on correlated path integrals through the theoretical "natural" homogeneous Kolmogorov turbulence spectrum. It has also been verified in limited field measurements of transmission correlations in smoke plumes.

s. TAWS (Target Acquisition Weapons Software) predicts the impact of weather and time of day on the performance of air-to-ground IR, TV, NVG and Laser precision guided munitions/target acquisition systems. Performance is expressed in terms of maximum detection, recognition, identification, or lock-on range. Results are displayed in graphic and tabular formats. TAWS is operationally employed by the Army, Navy, and Air Force.

t. WX4CM (Weather for Combat Models) is a series of parametric detection range curves constructed using TAWS with varied targets, sensors, and weather conditions. The resultant curves compare favorably with the tabular lookup methodology currently used in combat models. However, in addition to rapid execution, the curves add realism to wargames by allowing (variable) weather to be "played" without impacting run-time.

u. XSCALE (Scaled Extinction) is an empirical and approximate model for calculating transmittance through naturally occurring aerosols such as haze, desert aerosol, rain, fog, snow, and icefog. The wavelength range for XSCALE is 0.2 to 12.5 micrometers. Transmittances are generally broadband responses, although there is a capability to input a filter response function and an individual wavelength. The vertical scaling algorithm is based on measured data from cool, moist European environments.

3. Summary

The challenge to the weather effects community is to not only provide accurate and timely weather data products to the operators, but also tactical decision aids and algorithms that can relate the impact of the weather on systems performance for mission planning, selection of appropriate weapons for the current or forecast weather conditions, and inclusion into wargames. The programs and algorithms detailed above are readily available, fully documented, easily incorporated into other programs, and customizable to reflect different weapons systems configurations and mission profiles.

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